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THE MAGNET

Familiarly Described

by

CHARLES TOMLINSON.

19693:
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THE MAGNET:

FAMILIARLY DESCRIBED

AND

ILLUSTRATED BY A BOX OF MAGNETIC TOYS.

BY CHARLES TOMLINSON.

LONDON:
JOSEPH, MYERS, & CO., 144, LEADENHALL STREET.
1857.

BODLEIAN
D
13 AUG 1957
LIBRARY

LONDON:
THOMPSON AND VINCENT, PRINTERS,
GREAT ST. HELENS.

The Apparatus required for the Experiments mentioned in this little book is contained in a Box supplied by Messrs. JOSEPH, MYERS, & Co., and consists of the following articles:—

1. Two Bar Magnets with Armatures.
2. Horse-shoe Magnet and Armature.
3. Two Magnetic Fishes and Metal Rod.
4. One Magnetic Swan.
5. Iron Balls, about six in number, and of three different sizes.
6. Box of Iron Filings.
7. A Piece of Muslin.
8. A Knitting Needle or steel wire.
9. One Spinner.
10. Horizontal Needle, Stand, and Point.
11. Dipping Needle.
12. Compass.
13. Iron Nails or Brads of different sizes.

THE MAGNET.

WHEN a boy goes into a toy-shop to purchase some article suited to his taste and to the amount of his pocket-money, he is bewildered by the extent and the variety of the display. He has long since discovered the mysteries of top and marbles, of kite and ball, and though his relish for them is as keen as ever, he does not wish to expend his capital on any one of these objects, but would like to have something new. What shall it be? Casting his eyes around he sees hanging up in the window a magnet—a piece of steel bent into the form of a very long horse-shoe, with a bit of iron connecting the two ends which are of bright metal, while the rest of the horse-shoe is covered with sealing-wax, no doubt to prevent it from getting rusty.

And you, my young lady, deeply learned in the mysteries of dolls and the economy of dolls'-houses, will not, I am sure, object to put off for an hour the tea-party to which your dolls had invited the dolls of your school companion, while your brother exhibits to you the wonders of his newly purchased magnet. He will show you how it will take up mamma's scissors, run away with your own needles, and even make a needle move about on a plate if held underneath, and by rubbing it on the blade of a pen-knife it will enable that article to take up small bits of iron and steel. But your brother has soon shown you all that he knows about the magnet and you are anxious to get back to your dolls or perhaps to join your school-fellows in the game well-named *les Graces.* But suppose that instead of the horse-shoe magnet, papa or mamma, or some kind uncle or aunt, should present you and your brother with a box of magnetic toys, you would, I am sure, not object to give up a whole evening to an examination of their wonders.

Here is such a box:—it contains not only a magnet in the form of a horse-shoe, but also straight bar-magnets and a compass, which as you know very well is used by people on board ship, to enable them to find their way when out of sight of land on the open sea; here too are fishes and a swan and a number of other toys that perhaps you do not know the use of.

I am going to tell you something about all these things which I hope will amuse you. I will try not to be dull or difficult, and will not use many hard words. Should you, however, find me dull, the fault will belong to me and not to the magnet; for though the magnet may be in some respects difficult to understand, and some very hard words are used to explain much that it does, there are so many beautiful things to be learnt about it that you will, I am sure, not only wonder how such things can be, but also how they were ever found out.

It is more easy to remember a word and to understand the thing it is meant to express when we know how the word came first to be used, just as we take more interest in a person when we know his father and mother, sisters and brothers, than if he stood quite alone in the world. Now the word *magnet* is got from *Magnesia*, a place in Asia

Minor, where there is found a kind of iron ore which takes up pieces of iron and steel just as your brother's horse-shoe magnet does. The people who lived in this place a very long time ago called this dark stony-looking ore by the name of *magnes,* after the name of the place, from which we get our word *magnet.* A piece of this magnetic iron ore, properly shaped and arranged, so as to show its peculiar properties, is called a *natural magnet,* to distinguish it from steel magnets which are made artificially and are hence called *artificial magnets.* The natural magnet is also called a *lodestone,* from an old word signifying *leading* or *guiding* stone, because a great many hundred years ago people made use of this stone to guide them over wide deserts where there are no hills or houses, roads or finger-posts to show them the way.

By means of the natural, or artificial magnet, we can make another magnet out of a bar or wire of steel. In such a case we are said to *magnetise* the bar or wire, and the bar and the wire are said to be *magnetised.* The branch of knowledge which tells us about these things is called *magnetism;* and the person who makes this science his peculiar study is called a *magnetician.* There is no reason why a young lady should not study all that is known about this or any other branch of science. The laws of nature exert their influence on women as well as men, and all alike may suffer from neglecting them. There is nothing peculiar in a woman's mind which prevents it from a deeper insight into natural laws, and there is nothing peculiar in a man's mind that he should appropriate this knowledge to himself.

Let us now proceed to enquire into the properties of the magnet. The first and most obvious property of the magnet is its attractive force for pieces of unmagnetised iron and steel. This may be shown in various ways, as you well know. We will, however, give a few examples: if you will thread your needle, and hold it dangling in the air by the thread,—or still better, tie a piece of thin iron wire to a thread, and hold it in the same manner,—your brother will bring up the end of one of the bar magnets towards it, and you will observe that when the end of the magnet comes within an inch or two of the needle,

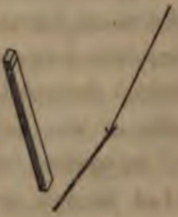

Fig. 1.

the latter will fly up to, and cling to it. (See fig. 1.)

This is what is called making an *experiment* or a *trial*, by which we find out something relating to the bodies or things operated on. In the case before us we learn that *your* bar-magnet exerts an attractive force or power over *your* needle. By trying the experiment with a great many magnets and a great many needles, we arrive at a more general conclusion, viz., that magnets exert an attractive force on needles. By hanging up a great variety of articles of different sizes, such as keys, pieces of wire, and other articles in iron and steel, and bringing up to them either end of a magnet, or the ends of various magnets of different sizes, we arrive at a still more general conclusion, namely, that the magnet attracts or draws to itself iron and steel. It is necessary, however, for this to be quite true, that the iron and steel should not be previously magnetic, or we shall have another property which will be noticed further on.

Let us now try another experiment on the attractive force: you will find in your box a *spinner*, consisting of a flat disk of brass with a piece of iron run through the centre. If you attempt with the end of the magnet to take up this spinner by the brass, you will fail to do so, because the magnet does not attract brass as it does iron or steel; but you will find that the end of the magnet will readily take up the spinner by its stem, and if you set it spinning on the table, as you would a teetotum, you can even then take it up, and it will go on spinning from the end of the magnet.

You will find in your box a number of iron bullets: you will be able easily to take up one with the end of the magnet, and to make it roll about while suspended therefrom. You will also be able to make a second bullet hang to the first, and the third to the second (see fig. 2), clearly showing that the magnetic force, whatever that may be, is continued to a distance from the end of the magnet through the first bullet to the second, and through the second to the third. That this force is derived from the magnet, and does not permanently reside in the bullets, may be proved by gently withdrawing the top bullet from contact with the magnet, when the second and

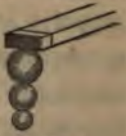
Fig. 2.

third bullets will fall away from the first. This experiment may be varied by placing a small key to the end of the magnet, an iron nail to the end of the key, a piece of iron wire to the end of the nail, a small needle to the end of the wire, and so on. On gently withdrawing the key, all the other bodies which it supported will fall.

You will find in your box a quantity of iron filings. Dip the end of the bar magnet into the filings, and observe how beautifully the iron particles arrange themselves in feather-like clusters. Here, as in the case of the bullets, one particle supports another and that supports a third, and so on throughout the vast number of particles taken up. Now wipe off the filings with your fingers, for you cannot shake them all off, and place the magnet flat down on a large sheet of paper, such as an old newspaper. Over the magnet place a sheet of clean writing paper, then pour the iron-filings into a piece of muslin, make it up into the form of a bag, and shake this over the paper under which the magnet lies. The filings will arrange themselves according to the form of the magnet, and if your brother will strike underneath the table two or three blows with his fist, so as to make the iron filings start up, they will in falling arrange themselves into a series of curves, proceeding outwards from the two ends of the magnet, and inwards so as to connect these two ends, these lines representing the directions of the force which resides in the magnet, and influences surrounding bodies, as it is also influenced by them, especially by bodies of iron and steel. If you move the paper over the magnet, the filings will move about wherever they come near to or pass over one of the ends of the magnet. Observe too, that if you sprinkle iron filings over the bare magnet, by far the largest quantity attach themselves to the two ends, and that the quantity rapidly diminishes as we approach the centre of the bar where there are no filings at all, or they

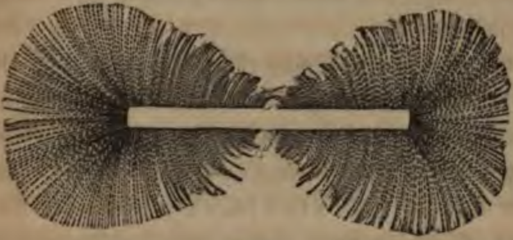

Fig. 3.

may be easily shaken off, by which we learn that the magnetic force resides chiefly if not entirely at the ends of the magnet. You may further prove this fact by endeavouring to suspend the bullets, keys and wires from different parts of the bar magnet.

Our experiments have thus far been made with the straight bar magnet. The horse-shoe magnet is nothing more than a bar magnet bent into that shape for the convenience of having the two ends near together. The two ends are connected by a piece of iron called a *keeper* or an *armature,* the use of which is to prevent the dispersion of the magnetic force. Straight bar magnets are usually arranged in pairs, with keepers or armatures connecting the two ends, as shown in fig. 4. If you hang up a horse-shoe magnet, and attach to its keeper a small scale-pan made of cardboard, you can add weights to the scale-pan until the keeper is pulled off. You can thus ascertain the strength

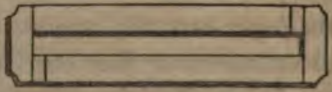

Fig. 4.

of the magnet. If you leave the scale-pan with nearly as much weight as the magnet can support attached to the keeper, the magnet will increase in strength from day to day, so that you may from time to time add to the scale-pan small weights, such as small shot. In this way we have heard of a magnet being made to support more than thirty times its own weight. Sometimes five or six horse-shoe magnets are placed side by side, and screwed together, forming what is called a *magnetic battery.*

We have thus far spoken of the attractive force of the magnet. We come now to notice another force, equal in amount and quite as remarkable, viz., the *repulsive* force. In order to show this, place the small magnetic needle by its central brass cap, upon the steel point, when you will observe that the needle will swing round and point to the north (see fig. 5.) You must keep the needle a few feet away from the other magnetic things in the box, and when it has settled down steadily

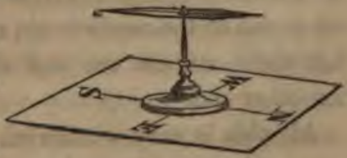

Fig. 5.

into a horizontal position, hold the end of one of the bar magnets level with it, at the distance of one or two feet, and you will observe that one end of the needle will turn round and point to the end of the bar magnet. If you slowly walk round the table keeping the bar magnet in the same horizontal plane, the needle will follow it wherever you go, provided the distance be not too great. This you see is another case of attraction. When however the needle is steadily pointing to the end of the bar magnet, if you suddenly turn the bar magnet round so as to present the other end to the needle, the needle will swing round and present its other end also. Try this as many times as you like, you will find that one end of the needle is always attracted by one end of the bar magnet, but that the same end of the bar invariably drives away or *repels* the other end of the needle;—in short, the end of the bar which attracts one end of the needle repels the other end.

All this is very wonderful. We are scarcely more able now than when the magnet was first discovered, to tell how it is that the magnet causes its invisible force to act upon the distant needle.

That there are lines of force proceeding from the ends of the magnet, through the air is evident from the experiment in which the iron filings were dusted over the bar magnet (see fig. 3), and it is easy to show that similar lines of force proceed from the ends of the magnetic needle. These sets of lines of force, mutually act and re-act upon each other in obedience to a certain law, which we understand, although the causes of that law may be as mysterious as ever.

You are quite aware that the magnetic needle points towards the north, which is called the direction of the needle, or simply the *magnetic direction,* and that its value in the compass, depends upon this property. A bar magnet properly mounted or hung up, so as to be free to move in a horizontal direction, will also swing round towards the north, and you will generally find the letter N marked on that end of the needle that points towards the north, while on the similar end of the bar magnet there is a notch, and also in some cases the letter N. In the horse-shoe magnet, a notch is also made in that end which would point to the north if the magnet were straight.

Of course, if one end of the straight needle or bar, points towards the north, the other end must point towards the south. It is usual to call these ends by the name of *poles:* the end that points towards the north is the north pole of the magnet, while the end that points towards the south is called the south pole. It is of no great consequence, whether we call them ends or poles, but as the latter word is the usual one, we will now adopt it.

Every magnet, then, has two poles: the line which joins them, and is supposed to pass through the centre of the straight bar, is called the *axis* of the magnet. Now let us repeat our last experiment, with a little more care, and in order to be quite sure which is the north pole of the needle, we will stick a little bit of paper on the point which is directed towards the north, so that when it is swinging round, there will be no difficulty in knowing, which is the north pole and which the south.

Present the north pole of the bar, to the north pole of the needle, and observe, that the north pole of the needle is repelled: the needle swings round, so as to place its north pole as far as possible from the north pole of the bar.

Present the south pole of the bar to the south pole of the needle and you will find a similar repulsion.

Present the north pole of the bar to the south pole of the needle and there will be a powerful attraction. The needle will swing round as if eager to come in contact with the bar, and a similar effect will be observed if you present the south pole of the bar to the north pole of the needle.

These effects may be observed with magnets of all sizes, whether the magnet operated on be a small compass-needle or a large bar magnet, or whether the operating magnet be large or small, straight or curved.

We learn from these experiments—1st, that two north poles repel each other; 2ndly, that two south poles repel each other; 3rdly, that a north pole and a south pole attract each other; 4thly, that a south pole and a north pole attract each other. All these four results may be concisely expressed in these words:—*poles of the same name repel; poles of different names attract each other.*

In performing experiments everything should be done with care and gentleness. Experiments, which may fail under an awkward or rough handling of the apparatus, will often succeed when a neat and gentle hand is employed. When I tell you that on bringing up one pole of the bar to a similar pole of the needle you cannot possibly make them attract each other (for that would be contrary to a law of nature), I do not mean to say that by holding the needle fast you cannot make its marked pole meet the north pole of the bar, for you obviously can do so; but this is not to use the apparatus fairly,—in fact, you injure it: you think you have made the north pole of the needle cling to the north pole of the bar, but you have done no such thing: nature is always true to herself and will not alter one of her laws to suit our caprice. Before the north end of the bar can attract the marked end of the needle it reverses the poles of the needle, the south pole taking the place of the north, and the north that of the south, so that the law above given still holds good. This reversal of the poles is not an uncommon accident when magnets are exposed to violence. If you throw a magnet down hastily on the table, or let it fall to the ground, you may not only reverse the poles but greatly weaken, or destroy altogether the magnetic force. A similar effect may be produced by the action of too high a temperature on the magnet. The mechanical violence occasioned by lightning striking a ship has been known to destroy the magnetism or reverse the poles of the ship's compass-needle.

You will take care in placing your bar magnets in the box to arrange the poles of opposite names side by side, and connect them with the keeper, (as shown in fig. 4) by which means the magnets retain their power: whereas, if the poles of the same names are placed side by side they injure each other. In the case of the magnetic battery already referred to, where five or six horse-shoe magnets are screwed together, poles of the same name are placed upon each other; but the effect of this arrangement is to produce one large magnet, the force of which is maintained by the armature which connects the opposite poles.

The magnetic fishes and the magnetic swan, which you will find in your box, depend for their action upon the law of opposite poles, which has been explained. Each fish contains in its body a piece of magnetised steel wire, running in the direction of the length or axis of the fish's body, with the south pole projecting from its mouth,—

so that when placed in a basin of water the fish will take up a position north and south. Accompanying the fish is a small metal rod, and the usual method of showing this toy is to put a small piece of bread on the point of the rod, and hold it over the basin. The fish will immediately swim up as if to seize hold of the bread, and attaching itself to the rod, it can be drawn out of the water. If before the fish has quite got up to the bread, you suddenly turn round the rod and present the blunted end, the fish will turn its head away, as if offended at being cheated. I need not of course take much trouble in explaining the action of this toy; the rod is a small magnet, the pointed end of which is the north pole; and as the fish's nose is the south pole, they attract each other. The blunt end of the rod being the south pole, of course repels the south pole at the fish's nose, and attracts the fish's tail, where the north pole is situate. If a couple of fishes be kept at rest in the water, they will beautifully illustrate the law of the opposite poles; they will arrange themselves just as you are directed to arrange your bar magnets (see fig. 4) side by side, the north pole of one corresponding with the south pole of the other and *vice versâ.* So with these fishes: the head of one will correspond with the tail of the other;—or if the magnetised wire does not extend all the way to the tail, the head or south pole of the fish will arrest itself at that part of the body of its companion where the north pole terminates. By operating on the fishes with a stronger magnet than the pointed rod, such as one of your bar magnets, and moving it round the outside of the basin, you will be able to make the fishes swim round in eager search of the attractive force. I must just beg you to remark how wonderful it is that the magnetic force is able to act through the substance of the basin, as, indeed, it will act through any other substance, unless it be made of iron or steel.

The magnetic swan has, of course, a piece of magnetised steel wire in its neck, the south pole of which is situate in or near the mouth, and the north pole terminates somewhere in the body. This magnet must, of course, be bent; but the bending does not, as you know in the case of the horse-shoe magnets, prevent it from acting,—only the curve must not form a complete circle, or it will not exhibit any magnetic power.

There is another toy called the *magnetic ship*, which acts in the same manner as the fishes and the swan.

We come now to consider some of the various ways by which the magnetic force may be given to other bodies, such as bars or wires of steel. If mamma will allow you to use one of her knitting needles, what I am going to describe will well repay the loss of it, for we shall presently have to break it to pieces. We are going to make a magnet of this knitting needle; but first of all, let us see whether it be not already magnetised, since steel articles are liable, from various causes, to become magnetic without our knowing anything about it. In order to ascertain whether a body be magnetic, we present one end of it to the magnetic needle whilst resting on its point (see fig. 5), and free to move on the application of a slight disturbing force. If the needle show attraction, we present the other end of the same body to the same pole of the needle; and if it still show attraction, we may be sure that the body is not magnetic,—since, if it were, one end would attract, while the other would repel the same pole of the needle. Now let us try the effect of the knitting needle: present one end of it to the north pole of the needle,—the needle swings up to it, thus showing attraction; present the other end to the same pole of the needle,—it again swings up to it, again showing attraction. You may, if you like, repeat the experiment with the south pole of the needle, although it is not necessary to do so; for it is quite impossible for the magnetic force to exist without repulsion being shown as strongly as attraction,—and the first experiment was sufficient to prove the absence of repulsion.

Let us now convert the knitting needle into a magnet, for which purpose place the needle upon a sheet of paper, and take your bar magnets one in each hand (as shown in fig. 6), the north pole of one pointing downwards, and the south pole of the other pointing downwards: in this position bring them down upon, and in contact with, the centre of the wire; press firmly with one of the magnets, and move the other slowly along the

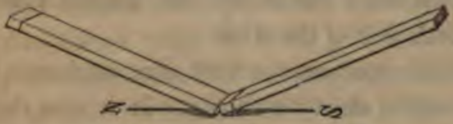

Fig. 6.

wire, quite to the end:—then, with a sweep of your hand, bring the magnet back to its original position: press the wire firmly with it, and withdraw the other magnet in a similar manner; with a sweep of the arm bring this magnet back to its original position, and repeat the operation with the first magnet, and again with the second magnet, and so on for half a dozen times, when you will find the knitting needle to be strongly magnetic,—that is, you have given it a north pole and a south pole; if suspended in the air by something that will not untwist, as a single line of floss silk, it will arrange itself north and south, just like the magnetic needle. Observe, that the north end of the bar magnet produces a south pole in the wire, while the south end of the bar magnet produces the north pole of the wire.

In this experiment a steel wire, such as a knitting needle, must be chosen. It is true that an iron wire can be magnetised, but it loses its magnetism so quickly that it will not answer our purpose.

What do you suppose now would be the effect if you were to break the magnetised knitting needle into two parts? You will probably say, that the north pole will be separated from its south pole, so that one part of the wire will exhibit only north magnetism, while the other part of the wire exhibits only south magnetism. But we have already found that one force cannot possibly exist without the other. If you have a north pole at one end, you must have a south pole at the other, and *vice versâ*; but then, you would say, there must be two new poles made by breaking the needle into two parts. Exactly so: however wonderful it may appear, it is nevertheless true that at the spot where the knitting needle was broken, two new poles appear, so that each piece instantly becomes a perfect magnet, as you prove by presenting the two ends of each respectively to the magnetic needle, when you find that the north pole of the wire remains the same as before, while its south pole is the broken end: the south pole of the knitting wire remains the same as before, while the north pole is the broken end. Now, suppose you break each part of the needle into smaller parts, as many as you please, you will find that each fragment is a perfect magnet: it will show attraction and repulsion of the magnetic needle, it will take up iron filings, and show the magnetic curves if it be covered with a piece of thin paper, and iron filings be dusted over it, (as in fig. 3) and if you run it through a small piece of cork, just sufficient to float it in water, it will take up a position north and south, and can be made to test the polarity of any of the other pieces of the knitting needle.

The horse-shoe magnet may also be used to magnetise a piece of steel wire, for which purpose place the wire upon a sheet of paper, and press upon its centre with the fore finger of the left hand (as shown in fig. 7): then take off the keeper from the horse-shoe magnet, and holding the magnet in the right hand, place its marked or north end down upon the wire close to your finger, and move it along the wire to the end, pressing moderately hard: then, withdrawing the magnet with a sweep of the hand, bring it down on the other wire on the other side of your finger, and with the unmarked or south pole rub the wire as before: then with a sweep of the hand bring the north pole to its first position, and rub

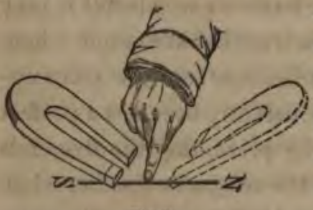

Fig. 7.

the half of the wire as before: repeat the process with the south pole, and so on for half a dozen times, when you will find the wire to be strongly magnetic.

The force which causes the needle to point towards the north, resides in the earth itself. In fact, the earth may be considered as an enormous magnet, having its north and its south pole; while the axis which forms the two, is nearly equal to the diameter of the earth, or about 8,000 miles. The north magnetic pole, is not the same as the geographical pole, or axis of the earth, but is situated about 24½° to the west of the true north. This is called the *magnetic variation* or *declination*, and is different in different countries, according to their position with respect to the north magnetic pole, while at some parts of the earth's surface, there is no variation at all (see fig. 12.) This of course happens at those places, where the north pole of the earth, and the north magnetic pole, are in the same line as the place in question; which line is called the *line of no variation*. In our own country, or at least at that part of it, where Greenwich Observatory is situated, the variation is, as already stated, 24½° W. In like manner the south magnetic pole, does not coincide with the south pole of the earth, but is situate about 24½° to the east of that point. The north magnetic pole, has been visited by our Arctic navigators, while the south magnetic pole has been approached within 160 miles.

The magnetism of the earth is very powerful, and exerts its influence upon everything upon its surface, although, we are not always aware of its influence. When bodies of iron and steel are left at rest in a north and south direction, they generally become magnetic by *induction*—that is, by a natural *leading in* of the earth's magnetism, and if you examine such things as fire-irons, which have been left undisturbed all the summer in a direction nearly north and south, it is very likely you will

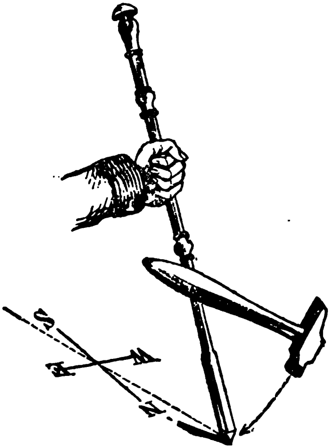

Fig. 8.

find them to be magnetic. You may, however, make a poker magnetic in a few seconds, by the action of the earth's magnetism upon it; if you hold it in the position shown in fig. 8, and strike it a few blows with a hammer, so as to make it ring. During this vibratory action, the particles are free to move, and turn round and adjust themselves in obedience to the magnetic influence; that is, they become *polar*; just as the iron particles do when they form those beautiful feathery clusters at the end of your bar magnet; each particle, in this case, has a north pole and a south pole, and an axis joining the two: the north pole of one particle attracts the south pole of the next particle, and in this way all the particles arrange themselves in a polarised form, as shown in fig. 9. Hence it necessarily follows, that one end of such a cluster must have all its particles with

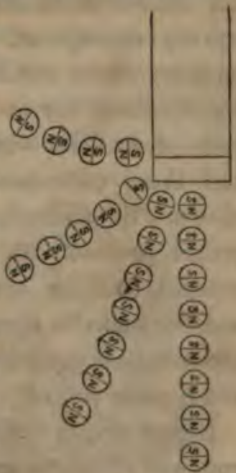

Fig. 9.

their north poles outwards, while the other end has all its particles with their south poles outwards, and will exhibit north magnetism at one end, and south magnetism at the other; while at points between the two the magnetic force is less appreciable, because we do not have the attracted ends of the particles presented to us. When we magnetise a piece of steel, such as the knitting needle, by rubbing a magnet upon it in the manner already described, we polarise its particles equally throughout, but the effects are as we have seen most manifest at the two ends or poles. By breaking the needle we evidently get at the ends of particles which were before in contact, and these ends become new poles as already shown. So also when the poker is held in a proper position with respect to the earth (which position will be better understood presently), and we make it ring, the particles immediately accommodate themselves to the earth's magnetism and become polar.

Before trying the experiment with the poker, you will of course see whether it is magnetic or not. Should the poker be a soft iron one, it will quickly lose its magnetism after being struck, but a poker of steel or of hard iron will answer the purpose admirably.

We have spoken of the direction of the magnetic needle being caused by the attraction of the poles of the earth, and we have seen that when the horizontal needle (fig. 5) is left undisturbed on its point or vertical axis, it arranges itself in the direction of the magnetic north and south. It must be evident, however, from our former experiments on attraction, that the north pole of the earth must have a tendency to pull the needle downwards towards itself, if the needle were so arranged as to be able to obey that impulse. Accordingly, if we mount the needle on a horizontal instead of a vertical axis, so that the needle is free to move in a vertical plane, the needle no longer remains horizontal, but one of its ends inclines downwards, or *dips*:—hence a needle of this kind is called a *dipping needle.* You will find one in your box, and it is also

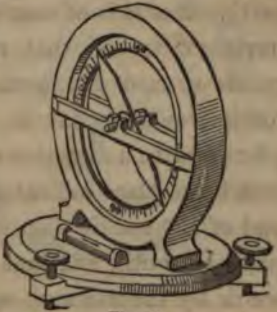

Fig. 10.

represented in fig. 10. We are going to perform a few experiments with this dipping needle. But first of all, I must call your attention to a point which may lead to some confusion in your knowledge of the laws of magnetism, unless you are cautioned respecting it. You know quite well that poles of the same name repel each other; and yet it is customary to call that the north pole of the needle that points to, or is attracted by the north pole of the earth. This, of course, is quite wrong, since poles of opposite names attract each other; and it is the south pole of the needle that is attracted by the north pole of the earth, and the north pole of the needle is attracted by the south pole of the earth. But it is of course more convenient to the navigator to call that end of the needle which points towards the north by the name of north; for it would appear as absurd to make a finger post point in a direction exactly opposite to that in which the place indicated is situated, as to call the end of the needle that points to the north by the name of south, and that which points towards the south by the name of north. Now, although the compass needle and the dipping needle both have their north or marked ends pointing towards the north, you will not let that circumstance disturb your appreciation of the perfect truth of the great magnetic law, that poles of the same name repel, while poles of opposite names attract each other.

Let us now examine our dipping needle. Place it on the table (a few feet away from the other magnetic things) in the line of the magnetic meridian, as it is called, or so that its ends may point nearly north and south, and you will observe that it does not occupy a horizontal position like the compass needle, but that one end dips so as to form an angle of 68° with the horizon; this is called the dip of the needle for the latitude of Greenwich. If we travel with the needle further north, the dip will increase; and if we go with it south, the dip will diminish: so that at the north magnetic pole the needle will be vertical, as shown in fig. 11, one end pointing exactly downwards, so as to make the needle

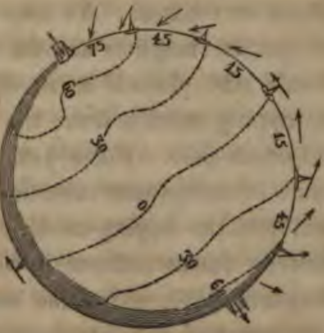

Fig. 11.

describe an angle of 90° with the horizon; while at the equator the ends of the needle, being balanced between two equal and opposite forces, viz., the north and the south poles of the earth, will remain quite horizontal. There is, of course, a line passing completely round the earth where the dipping needle is always horizontal, which line is marked zero or 0 degrees in fig. 11. This line is called the *magnetic equator:* it is not the same as the equator of the earth, but passes in some places to the north and in other places to the south of that line, so as to cut it about four times. We may represent, by means of our bar magnets and the dipping needle, what would take place if a traveller were to pass with a dipping needle from the north to the south magnetic pole. Place your bar magnet on the table in the proper direction, and over its north end hold the dipping needle; the needle will point directly downwards, as it would do at the north magnetic pole: move the needle slowly towards the centre of the bar magnet, and observe that its marked end gradually forms a smaller angle with the horizon. When the needle is over the centre of the magnet it will be quite horizontal, as it would be at the magnetic equator. Move the needle still onwards, as if you were travelling towards the south pole, and notice that the unmarked end of the needle begins to dip as it really does in the southern hemisphere; and it dips more and more, until we get to the south magnetic pole, when the unmarked end will point directly downwards, so as to form a right angle with the horizon. By moving the needle back to the north pole, all these effects will, of course, be repeated in the reverse order. The angle described by the dip in various latitudes is shown in fig. 11.

When the needle is pulled aside from its usual position, whether of direction or dip, it returns to that position by a series of oscillations, which may be few or many, according as the magnetic needle is near to or distant from the poles. This is called the magnetic *intensity* of the earth. Now the three magnetic *elements* as they are called,—viz, the *direction*, the *dip*, and the *intensity*,—are all subject to variation, at different parts of the earth's surface. We have spoken of the variation of the compass needle at London, as being about 24½° to the west of north. This was not always so. In the year 1658 the compass needle at London pointed exactly north and south, or due north as it is called. Before that year the marked end of the needle pointed to the east of north, and since that year it has pointed to the west of north. This westerly variation or declination as it is called, was at its greatest, or had reached its *maximum*, in the year 1815, when it was rather more than 24½°; since which time the westerly variation has been slowly diminishing, or in other words the direction of the needle is slowly coming back to the true meridian, or north and south line. This of course refers to the latitude of Greenwich. Similar changes are going on in other parts of the world, only their variation is different. Over one-half of the world the variation is easterly instead of westerly, and fig. 12 will give a rough idea of the direction of the needle at different points of the earth's surface. It will be seen that there are but few places where there is no variation, because, while the geographical meridians all tend to two

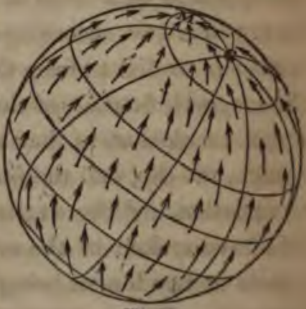

Fig. 12.

points or poles, viz, the ends of the earth's axis, the northern of which is marked G in fig. 12; the direction of the needle or magnetic meridians, tends to the magnetic poles, the northern of which is marked in our figure by the letter M. This point is about 19° from the north pole in the direction of Hudson's Bay, while the south magnetic pole is situate in the continent of Victoria Land, and has been approached within 160 miles. As we advance towards either of these points, the needle must of course vary considerably from the meridian, or north and south line, and change its direction very rapidly. At the magnetic pole the needle loses its direction, and points indifferently in any direction. Between the magnetic pole and the pole of the earth, the variation is more than 90°, so that the marked end of the needle points more to the south than to the north.

We may illustrate the influence of the magnetic pole upon the compass needle by one or two experiments. Place the two bar magnets side by side, with their north poles in the same direction, then bring down upon the north poles the horizontal needle or the small box compass, and you will find that the needle can be turned round indifferently, and will show no tendency to point in one direction more than another. One end of the needle will be powerfully drawn downwards by the attraction, but this end may be made to point indifferently to the east, to the west, to the north, or to the south, provided the centre of the needle be properly placed over the bar magnet. You will thus understand why the horizontal needle loses its direction at the pole, and regains it when taken to a distance therefrom, for it then acts as an attractive force, and the needle ranges itself in the line of that attraction; so we may also understand why, according to the observation of navigators in approaching the pole of the earth, the variation of

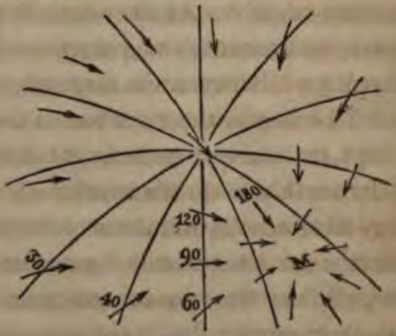

Fig. 13.

the compass increases rapidly. Place the bar magnet on the table, and let the north pole represent the magnetic pole of the earth, while a sixpence placed to the right of this pole, shall represent the north geographical pole: now bring the small compass gradually up towards the coin, and when placed thereon, you will find the variation to be upwards of 90°: some of these effects are represented in fig. 13, where M represents the north magnetic pole, and the various arrows show the positions of compass-needles.

You will now see the reason why we stated that the earth might be considered as a large magnet, since it influences all the magnets upon its surface, and gives them their direction, dip, and intensity. The magnetism of the earth is, however, distributed very unequally over its surface, so that it is impossible to calculate before hand, what is the direction of the needle at any particular spot. This must be found by experiment; by actually going to the place, and marking the result on a map or chart. This being done for a great many places, we thus get certain lines on our charts which are of great importance to the navigators. Thus the lines which pass through all the spots where the needle has the same direction, are called *lines of equal variation.* These lines are not regular curves, but very irregular and complex ones. *The line of no variation*, or that which passes through places where the needle points due north, is a waving line, passing through both the poles of the earth, and also through both the magnetic poles. In the year 1658, this line passed through England, but since that time, as already noticed, it has shifted to the west, so that it now passes through the two American Continents, while the other half of the line passes through Australia and China, and appears to be gradually approaching us, as the American line recedes; so that the magnetic poles probably have a very slow westward motion round the poles of the earth.

The lines of equal dip, or lines drawn through those places where the dipping needle makes the same angle with the horizon, are much more simple than those of equal variation: they resemble parallels of latitude, only irregularly waving, as shown in fig. 11, where the *line of no dip, or magnetic equator*, is marked with a zero. As the dip depends on the magnetic poles, it must, in common with all the magnetic lines, be gradually moving westwards; so that the dip like the variation, is constantly changing. The dip in England is slowly diminishing.

It must also be stated, that both the direction and the dip of the magnetic needle, undergo very small changes at different hours of the day, and at different seasons of the year; but the changes can only be observed with apparatus specially constructed for the purpose, and in buildings called Magnetic Observatories, properly arranged.

The magnetic intensity also varies irregularly over the earth's surface. In order to ascertain this, as well as the other magnetic elements, careful and laborious observations have been made with good instruments, in many parts of the world. For this purpose, expeditions have been sent out, and magnetic observatories fitted up at great cost to the British public, as well as to other nations, who are wise enough to see, that material prosperity is closely connected with advances in scientific knowledge. The increasing use of iron in the construction of ships, renders it necessary to be well acquainted with the effects of that metal on the ship's compass. The effect of masses of iron in the ship is to draw the compass needle out of its true position. The amount of error due to this cause must be nicely calculated and allowed for, or the ship would be in danger of being run ashore and wrecked, when the pilot thought he was in open water. In those parts of the earth, where the magnetic intensity is small, the ship's compass needle is the more disturbed by the iron on board than where it is strong; so that we see how important it is to know the variations in the magnetic intensity at different parts of the world.

The *mariner's compass*, as you are aware, consists of a magnetic needle, with a card attached, which *compasses* or includes all the points of the horizon. You will find a small pocket compass in your box, but this is not a mariner's compass; it is called a *land compass*, for the card in this case is not fastened to the needle, so as to swing round with it as in the mariner's compass, but is fixed to the bottom of the box, and the needle mounted on its point, moves over the card. A compass of this kind is very convenient for foot travellers when they want to know the direction in which they are travelling. As the needle points between

24° and 25° to the west of north, it is easy to place the card with respect to the needle, so that the *fleur-de-lis* shall point due north, and we can then choose the point we wish to follow, or ascertain which point we are actually following.

You are of course aware that the compass card contains thirty-two divisions, or in other words, the plane of the horizon is supposed to be divided into 32 parts, by lines drawn diametrically through the circle. These parts or divisions are called *points of the compass*, but the sailors call them *rhumbs.* The principal line in the compass card is that of the magnetic meridian, and the north point being the most important is usually marked with an ornamental arrow or *fleur-de-lis.* At right angles to this line is drawn another line, marked E, W, or east and west line, by which means we get the four *cardinal* or chief points. By drawing lines between these four points and passing through the centre, we get four other points, known respectively as *north-east, south-east, north-west,* and *south-west.* By continuing the division in the same manner, we get eight other points, which are named respectively from their position with respect to the eight principal points. Thus the point midway between N and NE is named *north-north-east*, as being nearer north than east. So also the point E and NE is termed east-north-east, as being nearer the east, and it is marked ENE. In a similar manner we have the points NNW and WNW for the points between north and west, SSW and WSW for the points between south and west, and SSE and ESE for the points between south and east. By continuing the division we get 16 more points, which are named from their positions with respect to the other points, with the addition of the word *by*, thus—the point midway between N and NNE is called north by east, and is marked N by E; that between N and NNW, north by west, and is marked NE by N, and so on, leaning for the designation towards the nearest of the four elementary cardinal points. Thus the point midway between E and ENE is termed east by north, and so marked E by N. In this way we arrive at 32 rhumbs or divisions of the circle into points, which taken in succession from the first or principal point, north, and carried round the circle in either direction, east or west,—suppose in the east direction, will stand thus:—

N.
N by E.
NNE.
NE by N.
NE.
NE by E.
ENE.
E by N.
E.
E by S.
ESE.
SE by E.
SE.
SE by S.
SSE.
S by E.
S.
S by W.
SSW.
SW by S.
SW.
SW by W.
WSW.
W by S.
W.
W by N.
WNW.
NW by W.
NW.
NW by N.
NNW.
N by W.

When you are able to remember and repeat all these points in their proper order, you are said to *box the compass.*

There are many other things respecting the magnet, and the ship's compass, which another day you would like to know, and you will find them described in larger works on magnetism. I must now take leave of you, hoping that this little book and the box of toys to which it refers, will possess the attractive without the repulsive property of the magnet.

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